

EUSUSTEL

***European Sustainable Electricity;
Comprehensive Analysis of Future European Demand and Generation
of European Electricity and its Security of Supply***

**WP5.2 „Comparison and Evaluation of Simulation Models and
Existing Scenarios for Electricity Generation“**

Draft Results for *ACROPOLIS* and *WETO*

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WP5: „Most Optimal Solution for Electricity Provision“

Objectives: Determine the total social cost for electricity generation, both statically and taking into account system interaction. Perform scenarios to determine the ‚most optimal solution‘ for electricity provision in the EU.

5.1: Determination of the overall static social cost for electricity

5.2: Comparison and evaluation of simulation models & codes and existing scenarios for electricity generation

5.3: Performing and interpreting four (contrasting) scenarios with one or two of the most appropriate models (with ‚improved‘ input data)

5.2 Comparison and evaluation of simulation models & codes and existing scenarios for electricity generation

Comparison and evaluation of five existing studies regarding electricity generation within the European Union until 2030. Analysis of main differences in results and their major reasons, taking assumptions on fuel prices, technological development, policies, etc. into consideration.

1. World energy, technology and climate policy outlook – WETO 2030
2. World Energy Outlook – WEO
3. European energy and transport – Trends to 2030
4. Assessing Climate Response Options: POLIcy Simulations – ACROPOLIS
5. Systems Analysis Promoting Induced Energy Technology progress – SAPIENT

5.2 ACROPOLIS and WETO: Main Focus of the Studies (1)

- *ACROPOLIS: Application and comparison of energy models to assess the impact of energy technologies and policy measures on greenhouse gases emissions and on sustainability in a global system analysis perspective. (Horizon: 1995 to 2030)*
- *WETO: Provide a reference scenario (business as usual) over the period 2000-2030 based on the POLES model. Contribution to the design of EU energy policy. Special focus was on the EU gas market and the GHG development in the business as usual scenario. Uncertainties have been analysed regarding resource estimates for oil and gas as well as technological development in electricity generation.*

5.2 ACROPOLIS and WETO: Scenario Variants beside BAU (1)

ACROPOLIS:

- Renewable Portfolio Schemes and Green Certificates
- International Flexible Mechanisms
- Efficiency Standards
- Internalisation of External Costs

WETO:

- Low oil and gas resources to evaluate the impact of higher fuel prices
- High gas resource case to evaluate the impact of structurally lower gas prices than oil prices
- Four technology development scenarios, regarding electricity generation
- GHG abatement scenario, implemented by a carbon value

5.2 ACROPOLIS and WETO: Models (2)

ACROPOLIS:

- 7 global models
 - CGE: AIM, GEM-E3, NEWAGE
 - IAM: DNE-21
 - LP-Macro: GMM, MESSAGE
 - Simulation: POLES
- 3 regional models (Western Europe, Nordic Regions, EU-15)
 - LP: MARKAL-Matter, MARKAL-Nordic
 - Optimizaton/Market Equilibrium: Primes
- 5 national models (Italy, Canada, USA, Germany, The Neth.)
 - LP-Macro: MARKAL-Macro-Italy
 - LP: MARKAL-Canada, TIMES-GER
 - Simulation: NEMS, NEV

WETO: POLES, Dynamic global simulation model

5.2 ACROPOLIS and WETO: Assumptions (3)

ACROPOLIS

- IPCC B2 scenario assumptions on population and GDP
- GDP development: 2.86 % per annum for 1995 - 2030
- Population growth rate: 1.13 % per annum for 1995 - 2030
- Modelers were free to assume region specific values.
- Energy-environmental policy measures until 2001.

WETO

- GDP development: >3.00 % per annum for 2000 - 2030
3.5 % (first decade), 3.1 % (second dec.), 2.6 % (third dec.)
Average GDP development for Western Europe: 2.1 %
Share of industrial countries on world GDP decreases to 45 %.
- Population growth rate: 1 % per annum for 2000 - 2030
Lower growth rates in EU, Japan and Pacific Region
- Energy-environmental policies until 2000: no Kyoto, no RES target, no nuclear phase-out

5.2 GDP and population growth rates as collected in WP2

GDP development for EU-25:

DoE, low: 1.7 % (2000-2025)
 DoE, high: 2.8 % (2000-2025)
 Primes: 2.4 % (2000-2030)
 WEO: 2.0 % (2000-2030)

WETO (WEU): 2.1 % (2000-2030)

Development of Population for EU-25:

Primes: +0.2 % (2000-2010)
 0.0 % (2010-2020)
 -0.1 % (2020-2030)
 0.0 % (2030-2050)

Fig. 2.4 Gross Domestic Product (growth rate)

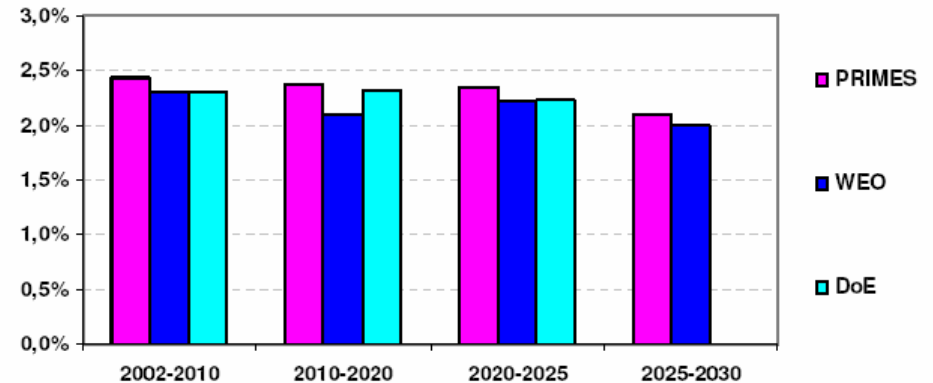
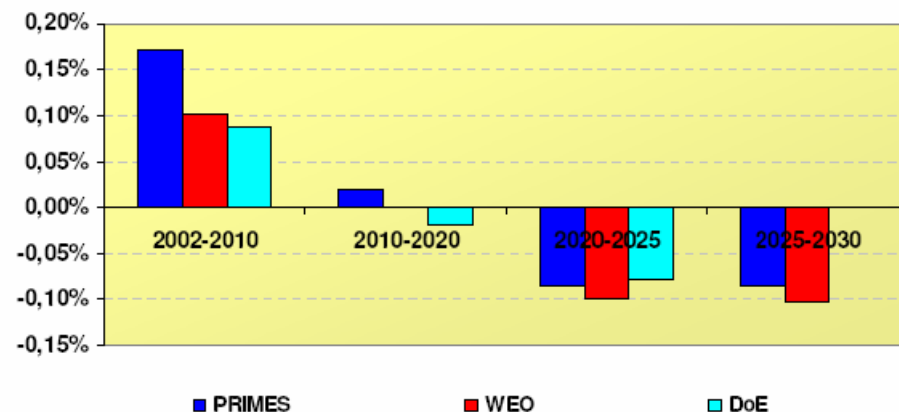


Fig. 2.2 Population growth rate to 2030



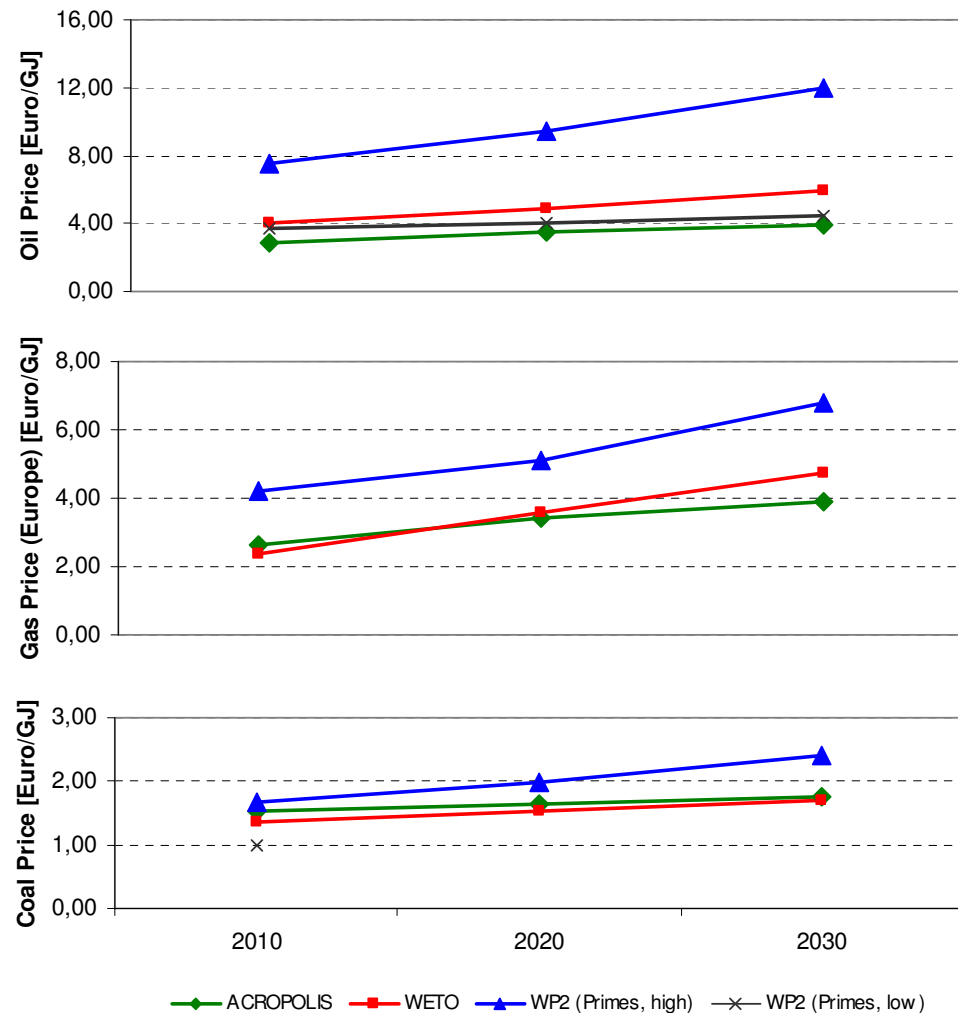
5.2 ACROPOLIS and WETO: Assumptions (4)

Fuel Price Development for Oil, Gas and Coal Prices until 2030 [Euro2000/GJ]:

ACROPOLIS (green line)
 WETO, Reference (red line)

WP2 – Primes, High Oil Price (blue line) and Low Oil Price Scenario (grey line)

Harmonized Assumptions within ACROPOLIS but endogenous within WETO (Poles).



5.2 ACROPOLIS: Scenario Assumptions (3)

Scenario assumptions:

1. Renewables

- EU-15: 22 % share of electricity consumption in 2010
- USA: 27 % share of electricity generation in 2020
- Minimum targets for other regions based on IIASA – 550 ppmv

2. International Flexible Mechanisms

- Soft Landing Scenario - 550 ppmv CO₂ concentration by 2150
- Annex B countries continue after first commitment period
- Non-Annex B countries targets based on GDP per capita and populations projections
- Hot Air from Russia and eastern Europe – only 50% by 2010
- No banking
- No Clean Development Mechanism

5.2 Models and Scenarios in ACROPOLIS (4)

Scenario assumptions:

3. Efficiency Standards for regions and sectors

- Energy efficiency improvement (%) against baseline

Sector/Region	2010	2020	2030	2040	2050
Power Sector					
Western Europe	3.75	7.50	11.25	15.00	18.75
N.America	3.44	6.88	10.32	13.76	17.20
Japan	1.25	2.50	3.75	5.00	6.25
EEFSU and ROW	2.50	5.00	7.50	10.00	12.50
Industry sector					
OECD & EEFSU	2.50	5.00	7.50	10.00	12.50
Developing World	3.75	7.50	11.25	15.00	18.75
Service & Residential					
OECD & EEFSU	5.00	10.00	15.00	20.00	25.00
Developing World	3.25	6.50	9.75	13.00	16.25
Transport - Road transport (car)					
Western Europe	2.50	5.00	7.50	10.00	12.50
N.America	5.00	10.00	15.00	20.00	25.00
Japan	1.40	2.80	4.20	5.60	7.00
EEFSU and ROW	2.95	5.90	8.85	11.80	14.75

5.2 Models and Scenarios for ACROPOLIS (5)

Scenario assumptions:

4. Internalisation of external costs for electricity generation

External cost per t of pollutant					
		NO _x	SO _x	particulates	CO ₂
average cost	/t	7000	8000	14000	19

	DESOX (%)	DENOX (%)	Dedust (%)	External costs (Eurocents/kWh)
Coal				
type 1	0	0	0	16.6
type 2	0	50	80	5.3
type 3	90	50	99.5	2.1
type 4	99	75	99.5	1.9
Gas				
boiler	-	0	0	2.8
combined cycle	-	90	90	0.3
Biomass				
	n.a.	n.a.	n.a.	0.3
Nuclear				
	-	-	-	0.5
Wind				
	-	-	-	0.1
Solar				
	-	-	-	0.1

5.2 Models and Scenarios for ACROPOLIS (6)

Models covering EU-15 or Western Europe with detailed representation of electricity generation sector:

- AIM
- DNE 21
- POLES
- MARKAL-Matters
- PRIMES

5.2 ACROPOLIS and WETO: Results (5)

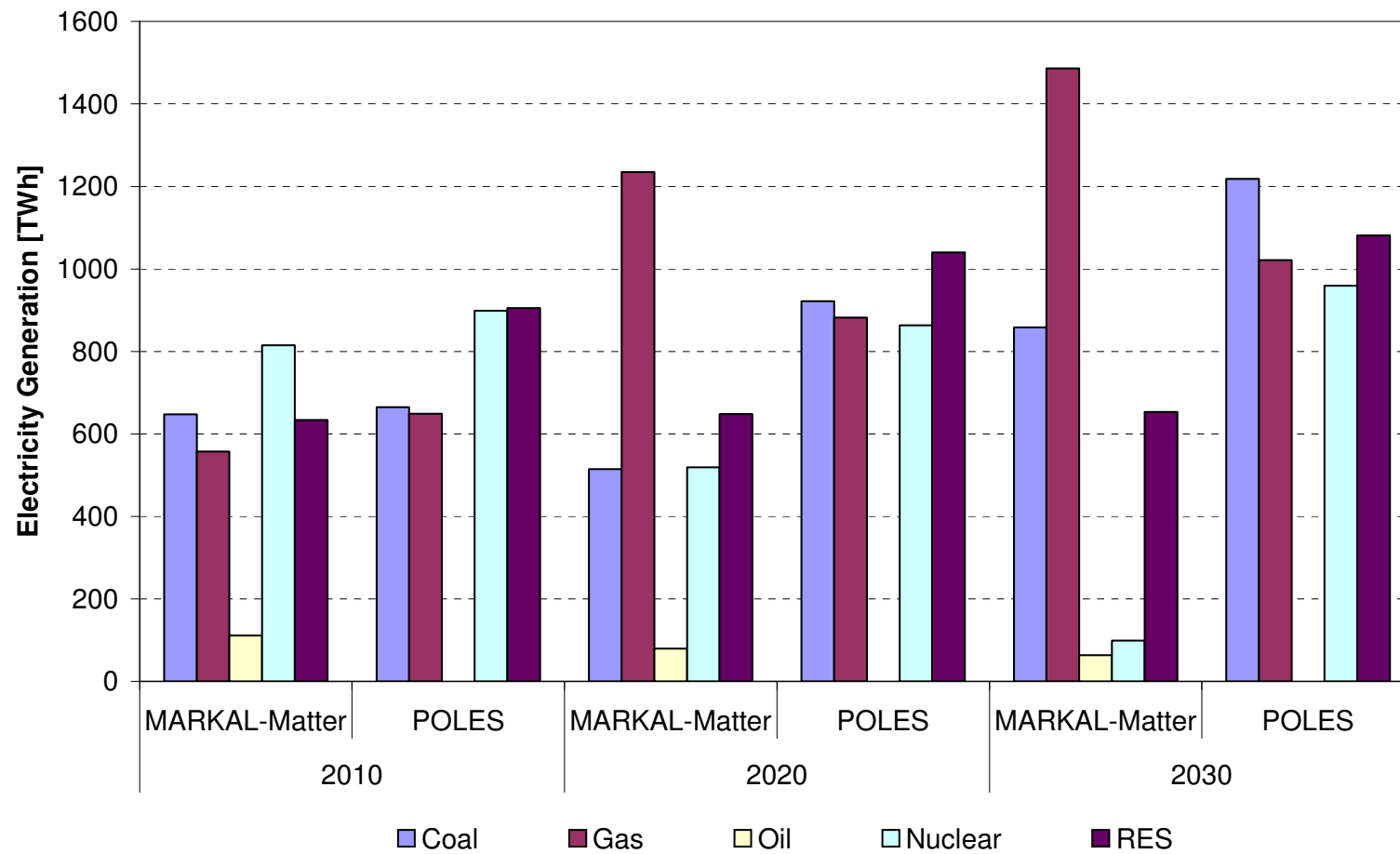
Model results for WEU (Baseline): MARKAL-Matter and POLES:

Indicator	Fuel	Baseyear	2000	2010	2020	2030
Cost of Electricity Generation [Euro₂₀₀₀/MWh]		28.04	21.70	37.47	42.02	41.25
GW_e	Coal	43.26	34.18	21.01	5.84	0.4
	Gas	26.45	45.92	37.13	41.76	31.64
	Oil	67.33	46.87	25.38	12.08	12.08
	Nuclear	118.41	126.66	124.03	78.99	15.09
	RES	168.86	186.19	215.49	218.58	220.44
TWh	Coal	762.2	894.7	647.2	514.4	857.8
	Gas	118.6	277.0	557.6	1234.8	1486.1
	Oil	180.6	111.1	111.2	79.4	63.5
	Nuclear	701.9	777.8	814.9	519.0	98.8
	RES	455.4	499.2	633.5	648.4	653.4
CO₂ Emissions by Electricity Generation [Mt]		n.a	n.a	n.a	n.a	n.a
Share of Domestic Primary Energy Supply [%]		55.8150	58.1477	50.4807	35.6193	32.0416

Indicator	Fuel	Baseyear	2010	2020	2030
Cost of Electricity Generation [Euro₂₀₀₀/MWh]					
GW_e	Coal				
	Gas				
	Oil				
	Nuclear				
	RES				
TWh	Coal	675.00	665.00	922.00	1218.00
	Gas	433	649.00	882.00	1021.00
	Oil				
	Nuclear	882.0	899.0	863.0	959.0
	RES	772.0	905.0	1040.0	1081.0
CO₂ Emissions by Electricity Generation [Mt]		1026	1013	1236	1429
Share of Domestic Primary Energy Supply [%]		65.15%	54.31%	43.99%	38.84%

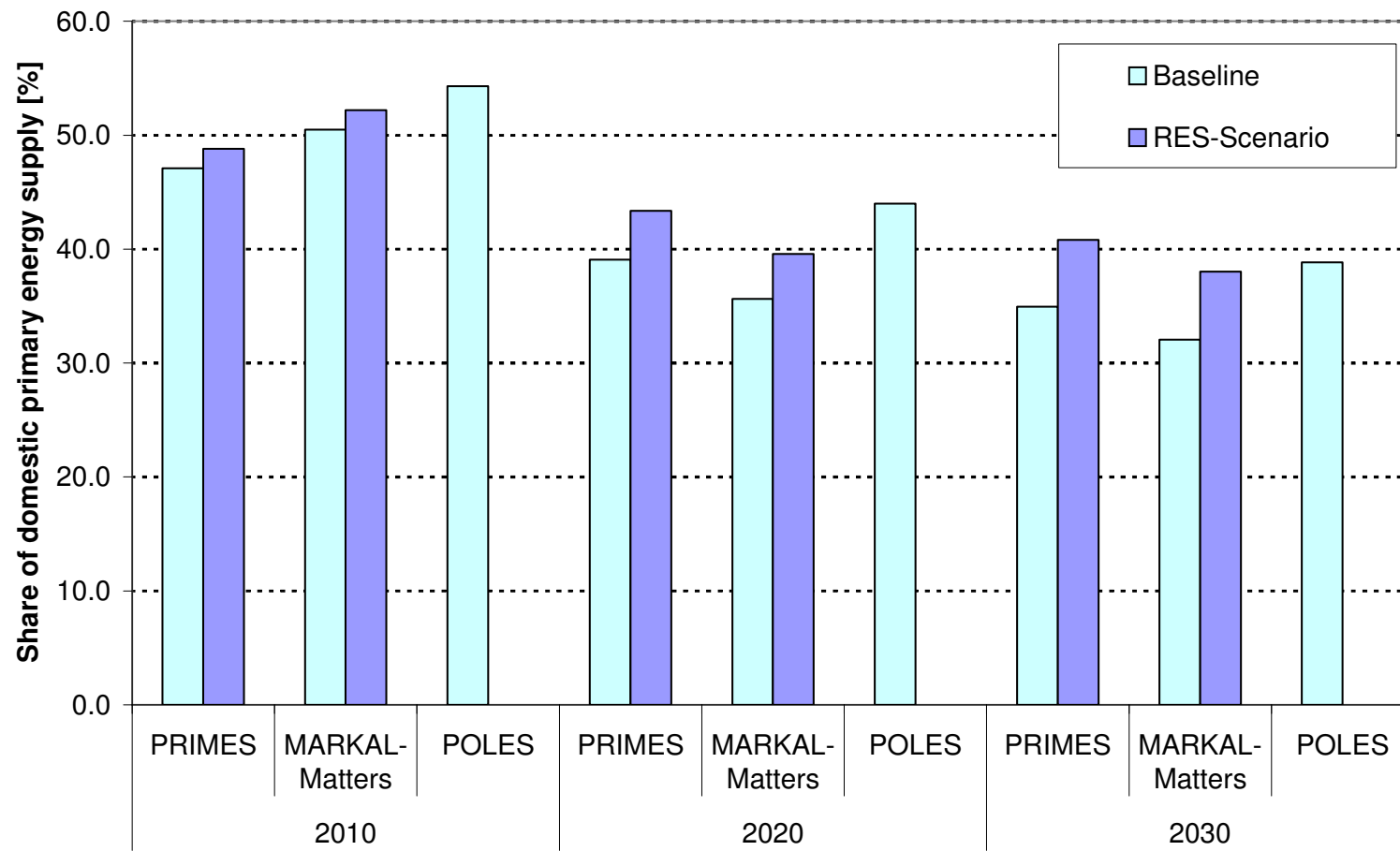
5.2 ACROPOLIS and WETO: Results (6)

Electricity generation in Western Europe (Baseline): MARKAL-Matter (ACROPOLIS) and POLES (WETO)



5.2 ACROPOLIS and WETO: Results (7)

Domestic primary energy supply in Europe: PRIMES: EU15, MARKAL-Matter: OECD90 WEU (both ACROPOLIS) and POLES (WETO, bau)



5.2 ACROPOLIS only: Results (1)

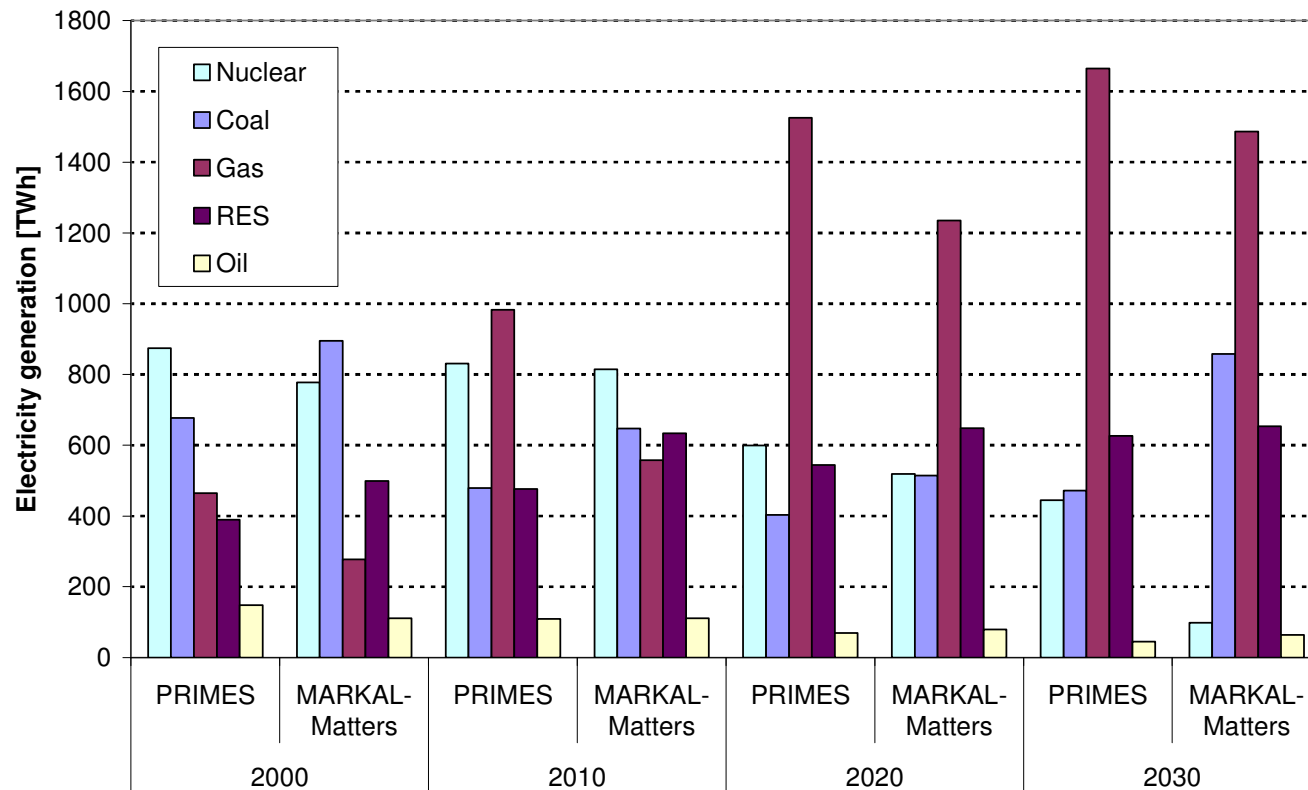
Model results of MARKAL-Matter: Comparison of Baseline and RES:

Indicator	Fuel	Baseyear	2000	2010	2020	2030	
Cost of Electricity Generation [Euro₂₀₀₀/MWh]		28,04	21,70	37,47	42,02	41,25	
Installed Electricity Generation Capacity and Production in Europe by Fuel	GW_e	Coal	43,26	34,18	21,01	5,84	0,4
		Gas	26,45	45,92	37,13	41,76	31,64
		Oil	67,33	46,87	25,38	12,08	12,08
		Nuclear	118,41	126,66	124,03	78,99	15,09
		RES	168,86	186,19	215,49	218,58	220,44
Installed Electricity Generation Capacity and Production in Europe by Fuel	TWh	Coal	762,2	894,7	647,2	514,4	857,8
		Gas	118,6	277,0	557,6	1234,8	1486,1
		Oil	180,6	111,1	111,2	79,4	63,5
		Nuclear	701,9	777,8	814,9	519,0	98,8
		RES	455,4	499,2	633,5	648,4	653,4

Indicator	Fuel	Baseyear	2000	2010	2020	2030	
Cost of Electricity Generation [Euro₂₀₀₀/MWh]		28,04	21,66	33,50	34,32	42,39	
Installed Electricity Generation Capacity and Production in Europe by Fuel	GW_e	Coal	43,26	34,18	21,01	5,84	0,4
		Gas	26,45	45,92	35,87	70,13	64,98
		Oil	67,33	46,87	25,38	12,08	12,08
		Nuclear	118,41	126,66	124,03	78,99	15,09
		RES	168,86	187,19	280,42	334,31	400
Installed Electricity Generation Capacity and Production in Europe by Fuel	TWh	Coal	763,98	895,04	609,81	474,91	689,36
		Gas	118,59	273,91	464,24	935,52	1088,23
		Oil	180,56	111,11	106,84	79,39	63,53
		Nuclear	701,94	777,78	814,88	518,96	98,78
		RES	701,94	501,46	814,08	984,37	1163,06

5.2 ACROPOLIS only: Results (2)

Electricity generation in Europe for the baseline: PRIMES: EU15 and MARKAL-Matter: OECD90 WEU



5.2 ACROPOLIS and WETO: Conclusion (8)

- ACROPOLIS and WETO can be compared regarding the business as usual scenario
- Alternative scenarios show significant differences in assumptions on prices, technologies and policies
- Deviations in baseline results are mainly caused by:
 - Assumptions regarding policies, fuel prices, GDP and population growth rates and technology specification
- Furthermore, assumptions on electricity generation technologies, e.g. specific investment cost which can vary broadly. Impact on model results is hard to analyse due to non-availability of data.
- Harmonization of data is important, if different models are going to be applied for further scenario analyses.